High Fidelity and Objectivity in Balance Assessment—A Comparative Study of the 6-Degree Motion Tracking for Body Balance Assessment to the Conventional Paper Test

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Abstract. Body balance is an essential capability for an individual to perform functional activities. There are various performance-based balance measures available to occupational therapists. However, conventional balance measures are limited due to subjectivity. There is a prominent need for a more objective and accurate assessment. NIMBLE, using motion sensing and tracking system was developed for a more objective and accurate measure of body movement with high-resolution recording. A pilot study was conducted in 20 participants for functional sitting balance measures by using both paper-based assessment and the NIMBLE. Results showed substantial discrepancies when the NIMBLE was able to detect balance deficits when the paper-based measures failed. The NIMBLE system can accurately capture the extraction of joint centers and segment orientation, providing the ability to calculate joint kinematics and spatiotemporal aspects of the movement. With this low cost and friendly interface, it has great potential to be widely used in healthcare practices.

Keywords: Balance · Measurements · Motion-sensing

1 Introduction

Body balance is an essential capability for an individual to perform activities of daily living (ADLs). There are various performance-based body-balance measures available to occupational therapy clinicians (OT) such as Postural Assessment Scale [1] for Stroke patients, Sitting Balance Scale (SBS) [2], Berg Balance Scale (BBS) [3], Function in Sitting Test (FIST) [4] and Functional Reach Test (FRT) [5]. However, the sitting balance measure is mostly limited to a paper test that is a scoring system for professionals to conduct the test with a subjective assessment. There is a prominent need for a more objective and accurate assessment. The NIMBLE is such a motion sensing and tracking system developed for objectively assessing patients' body balance in high-resolution motion recording. The system uses a six-degree sensing camera system that integrates depth assessment with traditional two-dimensional images. The patients' body motion is identified through a skeleton structure with key joint points. The program focuses on the patients' spinal movement highlighted by the spine-shoulder joints and pelvis as a base joint.

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A collaboration between the School of Occupational Therapy (OT) at Texas Woman's University (TWU) and the College of Architecture and Design at the University of Houston (UH) was established in Spring 2017. In Fall 2019, a team of researchers and undergraduate students continued to develop a motion capture system, the NIMBLE by using the Microsoft Kinect system for sitting balance measurement. The purpose of this proposed study is to examine the validity and reliability of this Kinect motion capture system comparing to current performance-based sitting balance measurements. The NIMBLE uses Microsoft Kinect as the main source to detect movement. The Kinect system incorporates an infra-red light and a video camera to create a 3D map of the area in front of it [6] and uses a randomized decision forest algorithm to automatically determine anatomical landmarks on the body, such as joint centers, in close to real-time [7]. The NIMBLE also uses open-source programming to record total travel distance, the velocity of movement, and fluidity during the sitting balance test.

2 Study

2.1 Participants

A pilot study was conducted at a senior activity center in two sessions. A convenience sampling of 20 participants took part in the balance assessment tests. Their age ranged between 60 and 94. Each participant was evaluated by two students simultaneously where one student used the conventional paper-based test and the other student used the NIMBLE system.

2.2 Testing Method

Each participant was tested using the following 5 tests to evaluate sitting balance. Each test was performed with the patient sitting unsupported on a stool with both feet on the floor. The NIMBLE system was set up in front of the patient (see Figs. 1 and 2 for setting).

Fig. 1. The testing setup with the Microsoft Kinect.

Fig. 2. A patient is being tested

Test #1. Sitting Unsupported with Eyes Open for 30 s. The paper test scored each patient between 0 and 4, 4 being the best score. The scores were as follows: (4) Able to sit safely and securely for 30 s. (3) Able to sit 30 s under supervision. (2) Able to sit 20 s. (1) Able to sit 10 s. (0) Unable to sit without support 10 s.

Test #2. Sitting Unsupported with Eyes Closed for 30 s. The scoring criteria are the same as the first test.

Test #3. Reaching Forward with the Outstretched Arm while Sitting. Patients were asked to make a fist and extend their arm forward to shoulder height (approximately 90 degrees). An object was placed 12 in. from the patient's fist in line with the patient's arm. The patient was asked to try to touch the object with their knuckles without losing balance. The paper test scored each patient between 0 and 4, 4 being the best score. The scores were as follows: (4) Can reach forward confidently > 10 in. (3) Can reach forward > 5 in. (2) Can reach forward > 2 in. (1) Reaches forward but needs supervision. (0) Loses balance while trying/requires external support.

Test #4. Pick Up an Object from the Floor. An object was placed on the floor 3 in. in front of the patient's toes. The paper test scored each patient between 0 and 4, 4 being the best score. (4) Able to pick up slipper without losing balance. (3) Able to pick up slipper but needs supervision for balance. (2) Unable to pick up slipper but reaches 1–2 in. from slipper and keeps balance independently. (1) Unable to pick up and needs supervision while trying. (0) Unable to try/needs assistance to keep from losing balance or falling.

Test #5. Reaching Laterally with an Outstretched Arm. Patients were asked to make a fist and extend their arm out to the side, laterally, to shoulder height approximately 90 degrees. An object was placed 12 in. from the patient's fist in line with the patient's arm. The patient was asked to try to touch the object with their knuckles without losing balance. The paper test scored each patient between 0 and 4, 4 being the best score. The scores were as follows: (4) Can reach laterally confidently > 10 in. (3) Can reach laterally > 5 in. (2) Can reach laterally > 2 in. (1) Reaches laterally but needs supervision. (0) Loses balance while trying/requires external support.

3 Results

The NIMBLE system captures body movements 10 frames per second and generates a spreadsheet displaying the exact movement increments and illustrating sketches to show movement. All 20 patients obtained a perfect score on the paper tests in all 5 tests which indicated no sitting balance deficits. However, according to the Nimble system, 6 out of the 20 patients showed movement that could not be picked up by eyes and relayed on the paper test. The following illustrations show how Nimble can pick up movement that can help Occupational Therapists be aware of patients' balance problems. Figure 3 shows a screen-capture example (Subject 001) of a perfect sitting test with eyes open unsupported for 30 s (Test#1). As in these displays, the graph on the left shows the testing subject's head movements from a top view. The graph on the right shows the testing subject's body movements in six-degree space representing by moving lines in three colors. The red line shows the forward and backward movement. The green line shows the right to left movement. The blue line shows the up and down movement. In Fig. 3, there are very few signs of any movement. Figure 4 and Fig. 5 show results from subjects 004 and 005 performing the same test but whose body moved backward and forward (the red line) that was nor picked up by the paper test.

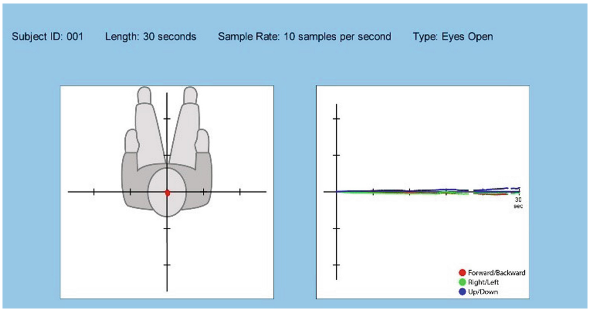

Fig. 3. Screen capture of a normal testing subject's test record. (Color figure online)

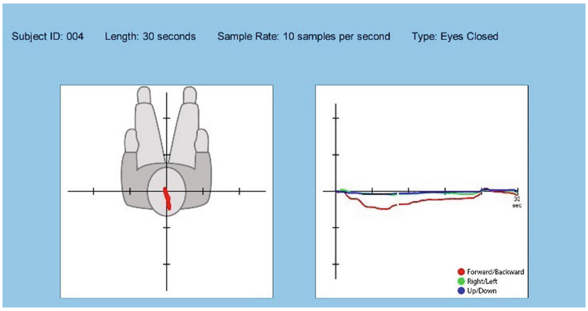

Fig. 4. Screen capture of the testing subject 004. (Color figure online)

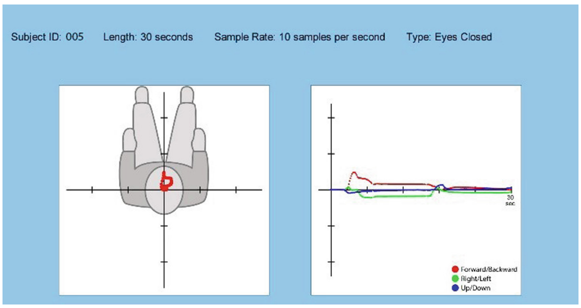

Fig. 5. Screen capture of the testing subject 005. (Color figure online)

Figure 6 shows the subject 011 in a perfect performance of the reaching forward test (Test#3) in a normal person. Figure 7 illustrates subject 004 taking a longer time than expected to complete the test. Figure 8 is an example of one subject leaning backward and returning.

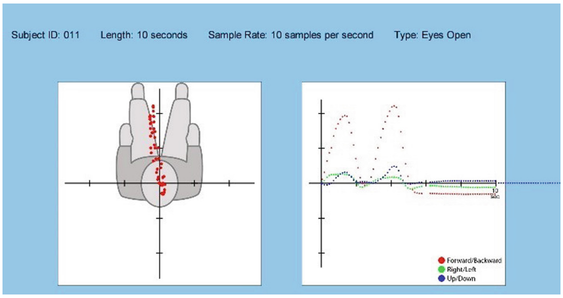

Fig. 6. Subject 011 in a leaning forward test.

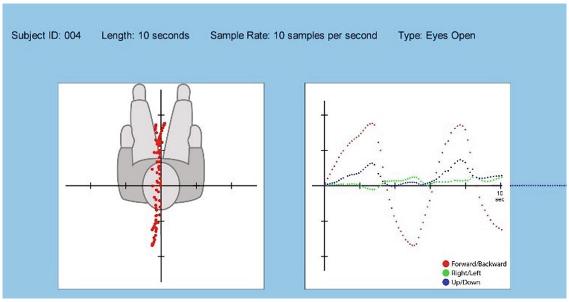

Fig. 7. Subject 004 in a leaning forward test.

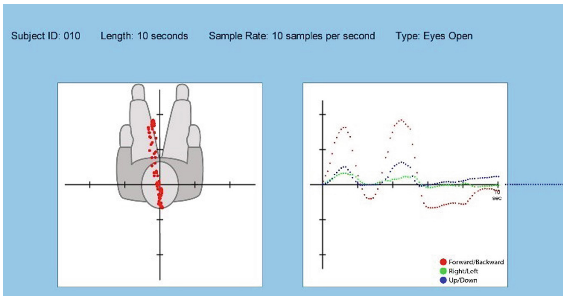

Fig. 8. Subject 010 in a leaning forward test.

Figure 9 is an example of a normal performance to pick up an object from the floor (Test#4). On the contrary, Fig. 10 is an example of participant 005 that moved backward when returned to his starting position. Figure 11 is an example of participant 003 who overshot the target when reaching down.

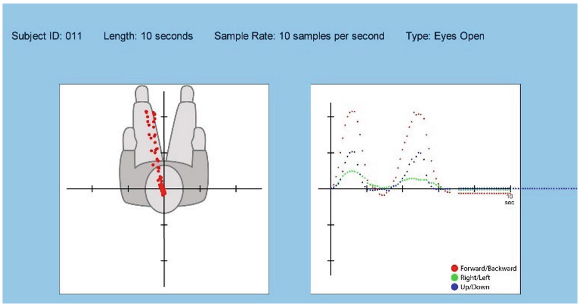

Fig. 9. Normal performance to pick up an object from the floor

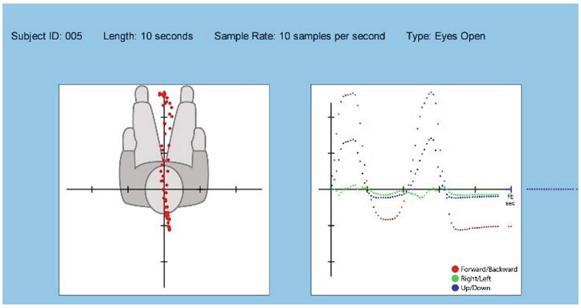

Fig. 10. Participant 005

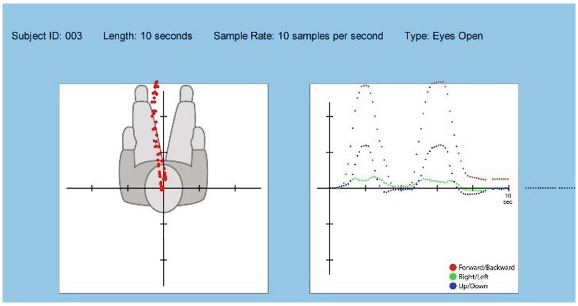

Fig. 11. Participant 003

4 Conclusion

The NIMBLE has shown an excellent capability to capture human body movements when paper-based tests failed to detect balance deficits. The NIMBLE uses a low cost and user-friendly motion sensing and tracking system to measure balance and has a great potential to be used in various healthcare settings. Through the NIMBLE, data is generated and collected on a large scale and the data can be calculated and visualized to show patients' balanced state in a high resolution. The NIMBLE is an objective balance assessment tool that is precise and accurate to measure total travel, velocity, and fluidity of human movement.

References

1. Benaim, C., Perennou, D.A., Villy, J., Rousseaux, M., Pelissier, J.Y.: Validation of a standardized assessment of postural control in stroke patients: the Postural Assessment Scale for Stroke Patients (PASS). Stroke **30**(9), 1862–1868 (1999)
2. Medley, A., Thompson, M.: Development, reliability, and validity of the Sitting Balance Scale. Physiotherapy Theor. Pract. **27**(7), 471–481 (2011)
3. Berg, K., Wood-Dauphinee, S., Williams, J., Gayton, D.: Measuring balance in the elderly: preliminary development of an instrument. Physiotherapy Can. **41**, 304–311 (1989)
4. Gorman, S.L., Harro, C.C., Platko, C., Greenwald, C.: Examining the function in sitting test for validity, responsiveness, and minimal clinically important difference in inpatient rehabilitation. Arch. Phys. Med. Rehabil. **95**, 2304–2311 (2014)
5. Duncan, P.W., Weiner, D.K., Chandler, J., Studenski, S.: Functional reach: a new clinical measure of balance. J. Gerontol. **45**(6), M192–M197 (1990)
6. Menna, F., Remondino, F., Battisti, R., Nocerino, E.: Geometric investigation of a gaming active device. Proc. SPIE Int. Soc. Opt. Eng. **8085**, 80850G (2011)
7. Shotton, J., Fitzgibbon, A., Cook, M., Sharp, T., Finocchio, M., Moore, R., et al.: Real-time human pose recognition in parts from single depth images. In: Proceedings of the IEEE Computer Society Conference (2011)